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Food and feeding habits of *Caranx crysos* from the Gulf of Gabès (Tunisia)

AYDA SLEY[1], OTHMAN JARBOUI[1], MOHAMED GHORBEL[1] AND ABDERRAHMEN BOUAIN[2]

[1]Institut National des Sciences et Technologies de la Mer (Centre de Sfax), BP, 1035,3018, Sfax, Tunisie, [2]Faculté des Sciences de Sfax. BP, 802–3018 Sfax, Tunisie

The diet of blue runner Caranx crysos *(Carangidae) in the Gulf of Gabès (Tunisia, Mediterranean) is described from analysis of stomach contents (N = 1668 fish). The majority of samples were obtained from commercial purse seine and gill-net catches. The index of vacuity (%VI) was relatively high (58.7%) and differed significantly across months. Blue runner is an opportunistic predator that consumes mostly pelagic organisms, with benthic prey representing only a small proportion of the diet. The diet was quantified using the frequency of occurrence (%F), numerical abundance (%N), weight (%W) and the index of relative importance (IRI and %IRI) for each prey taxa.*

The most important prey categories were teleosts (%IRI = 83.4) and crustaceans (%IRI = 16.6), with molluscs only observed occasionally (%IRI < 0.1). Fish were also the dominant food items in both terms of weight (89.60%) and frequency of occurrence (82.44%). In terms of numerical abundance, crustaceans were the most abundant prey (78.07%). Ontogenetic and seasonal differences in the diet were observed, although there was no difference between the diets of males and females.

Keywords: Carangidae, *Caranx crysos*, diet, Gulf of Gabès, Tunisia, Mediterranean

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INTRODUCTION

Blue runner *Caranx crysos* (Mitchill, 1815), is a one of the most important commercial carangids in Tunisian waters, and is also an important component of the marine ecosystem in the coastal waters of the Gulf of Gabès. Annual catches of this species are included in one statistical category that combines both the genera *Caranx* and *Trachurus*.

This coastal pelagic carangid is found in the western Atlantic from Nova Scotia to Brazil (McKenney *et al.*, 1958) and throughout the eastern Atlantic and Mediterranean Sea, and may be found as far north as the British Isles (Swaby *et al.*, 1996). This medium-sized fish, commonly attaining 400 mm fork length (Cervign *et al.*, 1993), is generally found in large schools, and can be the dominant species in the fish assemblage in some areas (e.g. Sonnier *et al.*, 1976; Stanley & Wilson, 1997, 2000).

There have been comparatively few studies on the biology of *Caranx crysos* (e.g. Goodwin & Finucane, 1985; Goodwin & Johnson, 1986). Several studies have discussed the feeding habits of larval and juvenile blue runner (McKenney *et al.*, 1958; Schekter, 1972, Christmas *et al.*, 1974), whilst accounts of the adult feeding habits are mostly anecdotal (Randall, 1967; Keenan & Benfield, 2003). The purpose of the present study was to investigate the feeding habits of *C. crysos* in the Gulf of Gabès (Tunisia), and examine the effects of sex, predator size and season on the stomach contents.

Corresponding author:
A. Sley
Email: sley_aida@yahoo.fr

MATERIALS AND METHODS

The Gulf of Gabès spreads along 750 km of the southern Tunisian coasts, from 35°N to the Libyan border. This region is characterized by a broad continental shelf, a rare feature of the Mediterranean (Ben Othmen, 1973).

Samples of *C. crysos* were taken from commercial catches from purse seine and gill-net operating from June 2004 to May 2006. The stomach contents of 1668 *C. crysos* were examined, ranging in size from 85–358 mm fork length (FL) and 8–880 g wet bodyweight (BW).

Most fish were examined fresh, shortly after landing. The weight of each specimen was measured with a digital balance to the nearest 0.1 g. Fork length and total length were measured to the nearest millimetre. Sex and time of capture were also recorded for each fish.

In the laboratory, the stomach contents were removed, and the prey identified to the lowest taxon practical (Fischer *et al.*, 1987a, b).

The number of prey found in each stomach was recorded to determine the feeding pattern of *C. crysos*. Each prey item was weighed in wet condition to the nearest 0.001 g.

No single method of analysis of stomach contents completely describes the diet of a predator (Hyslop, 1980); hence, the index of vacuity (%VI) was calculated to describe the trophic behaviour of this species. We evaluated the importance of the different prey types by calculating the frequency of occurrence (%F), abundance by both number (%N) and weight (%W). These indices were used to calculate the index of relative importance (IRI) (Pinkas *et al.*, 1971; Hacunda, 1981; Cortés, 1997) for each taxonomic category, using mass instead of volume. This index facilitates comparisons to other studies, provides a single measure of the diet, and is

less biased than weight, frequency or number alone (Cortés, 1997).

In the present study, the following formulae of these indices were used:

(1) vacuity index (%VI) = number of empty stomachs/total number of examined stomachs* 100;
(2) frequency of occurrence (%F) = number of stomachs in which a food item was found/the total number of full stomachs * 100.

* Percentage of numerical abundance (%N) = total number of each prey item/the total number of all prey in all stomachs * 100.
* Percentage biomass (%W) = total wet weight of each prey item/the total weight of stomach contents* 100.
* The main food items were determined using the IRI:

$$IRI = \%F * (\%N + \%W);$$

Morato-Gomes *et al.* (1998) proposed a classification according to the following subdivision:

Main prey: $IRI \geq 30 \times (0.15 \times \sum F\%)$
Secondary prey: $10 \times (0.05 \times \sum F\%) \langle IRI \langle 30 \times (0.15 \times \sum F\%)$
Occasional prey: $IRI \leq 10 \times (0.05 \times \sum F\%)$.

The index was expressed in percentage as follows: % IRI = (IRI/$\sum$ IRI) *100

Prey species were sorted in decreasing order according to IRI and the cumulative %IRI was calculated and recorded for the major prey taxa (Hyslop, 1980) and compared between different size-groups, seasons and sex. This index was examined for three size-groups that corresponded roughly to juveniles (≤18 cm FL), medium size fish (18.1 ≤ FL ≤ 26 cm) and adults (>26 cm FL).

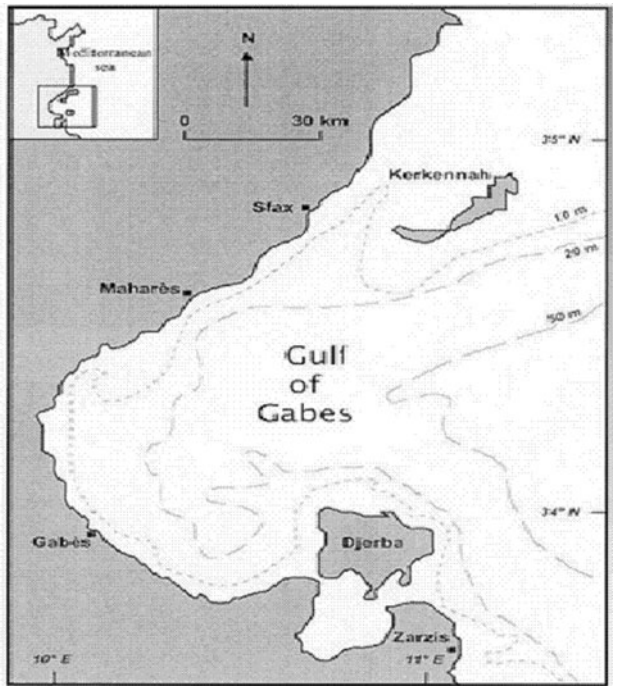

Fig. 1. Map of the Gulf of Gabès (Tunisian coasts).

Statistical differences ($P < 0.05$) in diet composition with respect to length-class and season were assessed by Chi-square test (χ^2) of the frequency of a given prey (Sokal & Rohlf, 1981). The variation in the index of vacuity (%VI) was also tested using the χ^2-test over a contingency table of number of empty stomachs.

RESULTS

Feeding intensity

Of the 1668 specimens examined, 979 (58.7%) had empty stomachs and 689 specimens (41.3%) had stomachs containing food. The proportion of empty stomachs did not differ significantly between the sexes ($\chi^2 = 0.84$, $P > 0.05$), and the %VI of females and males were 57.5% and 59.7%, respectively. The index of vacuity varied significantly over the year ($\chi^2 = 306.19$, $P < 0.05$). The highest number of empty stomachs was found in March (97%) and January (89%), and was lowest from June to August (21.1–45.6%) (Figure 2).

The proportion of empty stomachs was also significantly different among size-classes ($\chi^2 = 37.02$, $P < 0.05$), with the %VI of juveniles (≤18 cm FL), medium-size fish and adults 55.5%, 64.3% and 27.6%, respectively.

Diet composition

The diet of *C. crysos* consisted of 3721 different prey items across 14 identified prey taxa with an average of 5.4 prey items per stomach for fish containing food.

The observed prey were either teleosts, crustaceans or molluscs (Table 1), with teleosts and crustaceans the main groups, as indicated by %IRI for these groups (83.4 and 16.6%, respectively). Molluscs were only found occasionally (%IRI < 0.1), and were omitted from subsequent analyses and figures.

Although fish were most important in terms of weight (89.6%) and frequency of occurrence (82.4%), crustaceans were the most numerous group (78.07%), due to mysids and penaeid shrimps occurring in large numbers.

At the family level, engraulids (*Engraulis encrasicolus*) were the most important prey in terms of weight (43.7%), whereas penaeids (*Metapenaeus monoceros* and *Penaeus kerathurus*) and mysids (*Leptomysis mediterranea* and *Siriella clausi*) were numerically the most important prey, accounting, respectively, for 43.5% and 40.5% of the diet (%N).

According to the classification of Morato (1998), the main prey (IRI ≥ 476.8) were engraulids (IRI = 1266.9; %IRI =

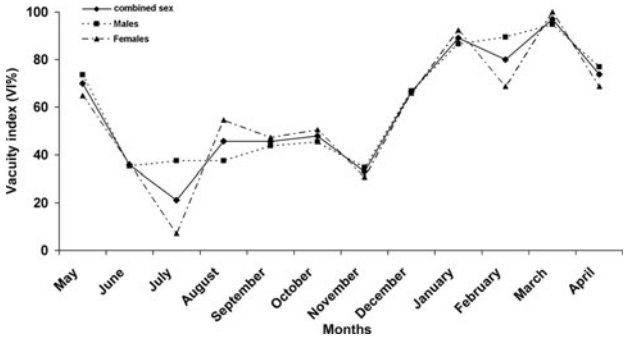

Fig. 2. Variation in percentage of the vacuity index (VI%) among sex throughout the year of *Caranx crysos* from the Gulf of Gabès.

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Table 1. Prey categories of *Caranx crysos* from the Gulf of Gabès (Tunisia), with the proportion of the diet by frequency of occurrence (%F), number (%N), biomass (%W), IRI and %IRI. Prey taxa also classified as main prey species (M), secondary prey species (S) and occasional prey (O), according to the classification of Morato-Gomes *et al.* (1998).

Group	Order or family	Item	N. est./it	%F	N. pr./it	%N	W. pr./it (g)	%W	IRI	%IRI	Category
Teleosts	Engraulidae	*Engraulis encrasicolus*	166	24.09	330	8.87	893.98	43.71	1266.88	11.54	M
	Clupeidae	*Sardinella aurita, Sardina pilchardus*	129	18.72	178	4.78	507.45	24.81	554.15	5.05	M
	Belonidae	*Belone belone*	11	1.60	11	0.30	22.31	1.09	2.21	0.02	O
	Gobiidae	*Gobius niger*	5	0.73	7	0.19	11.07	0.54	0.53	0.005	O
	Sparidae	*Diplodus vulgaris*	5	0.73	7	0.19	11.11	0.54	0.53	0.005	O
	Serranidae	*Serranus hepatus*	5	0.73	7	0.19	11.85	0.58	0.56	0.01	O
		Non-identified teleosts	247	35.85	257	6.91	374.59	18.32	904.24	8.24	
Total teleosts			568	82.44	797	27.48	1832.4	89.60	9152.21	83.39	
crustaceans	Penaeidae	*Metapenaeus monoceros, Penaeus kerathurus*	97	14.08	1261	43.48	137.92	6.82	708.12	6.45	M
	Mysidacea	*Leptomysis mediterranea*	10	2.18	797	18.41	11.15	0.34	40.81	0.37	
		Siriella clausi	12	1.74	821	22.06	22.58	1.10	40.35	0.37	
	Total mysidacea		22	3.92	1618	40.47	33.73	1.44	81.17	0.74	S
	Isopoda		6	0.87	6	0.16	3.84	0.19	0.30	0.003	O
	Squillidae	*Squilla mantis*	2	0.29	2	0.05	7.85	0.38	0.13	0.001	O
	Natantia		1	0.15	1	0.03	0.5	001	0.01	0.0001	O
		Non-identified crustaceans	15	2.18	17	0.46	11.83	0.58	2.25	0.02	
Total crustaceans			143	20.75	2905	78.07	195.66	9,57	1818.90	16.57	
molluscs	Sepiidae	*Sepia officinalis*	3	0.87	3	0.16	0.874	0.28	0.38	0.003	O
	Teuthoidea		4	0.58	4	0.11	8.2	0.40	0.30	0.003	O
	Octopodidae	*Octopus vulgaris*	6	0.44	6	0.08	5.63	0.04	0.05	0.0005	O
	Total cephalopoda		13	1.89	13	0.35	14.7	0.72	0.73	0.007	
	Gastropoda		6	0.87	6	0.16	2.32	0.11	0.24	0.002	O
Total molluscs			19	2.76	19	0.51	17.023	0.83	3.70	0.03	

N. est./it, number of stomachs containing prey i; N. pr./it, number of prey item i; W. pr./it (g), wet weight of prey item i; M, main prey (IRIi $\geq$ 476.8); S, secondary prey (53 $<$ IRIi $<$ 476.8); O, occasional prey (IRIi $\leq$ 53).

11.6), penaeids (IRI = 708.1; %IRI = 6.5) and clupeids (*Sardinella aurita* and *Sardina pilchardus*) (IRI = 554.2; %IRI = 5.1) (Table 1). Mysids were of secondary importance (IRI = 81.2 and %IRI = 0.7) and other taxa only taken occasionally (IRI ≤ 53).

The %IRI of teleosts and crustaceans in female blue runner (88.4% and 11.5%, respectively) were similar to that observed in males (81.9% and 18%, respectively).

Based on the %F of each major food group, the differences in the diet composition between sexes were not significantly different (teleosts: $\chi^2 = 0.8$, $P > 0.05$; crustaceans: $\chi^2 = 0.9$, $P > 0.05$) (Table 2; Figure 3).

Ontogenetic differences in the diet were apparent, and the frequency of crustaceans decreased significantly with increasing predator size ($\chi^2 = 38.3$, $P < 0.05$), and the frequency of teleosts increased significantly ($\chi^2 = 35.2$, $P < 0.05$).

In fish <180 mm FL, teleosts and crustaceans accounted for 67% and 33% IRI, respectively, whilst the diet of the two larger size-classes (18.1–26 cm and >26 cm FL) consisted almost exclusively of fish (%IRI = 95–99.8), and crustaceans were of lesser importance (%IRI = 5–0.13) (Table 3; Figure 4).

Significant differences in the diet between seasons was also observed, both for teleosts ($\chi^2 = 8.7$, $P < 0.05$) and crustaceans ($\chi^2 = 20.4$, $P < 0.05$). Fish were the main prey group, especially in the spring (%IRI = 99%), and although crustaceans were present in the stomachs throughout the year, there was a peak value recorded in winter (%IRI = 13.5). Molluscs were only found in winter and autumn (Table 4; Figure 5).

DISCUSSION

In this study, the diet composition of blue runner *Caranx crysos* in the Gulf of Gabès was found to be broadly similar to those of related species in the family (Overko, 1978; Maigret & Ly, 1986; Chavance *et al.*, 1991; Marchal, 1991), indicating that this species is piscivorous, and predates mostly on small, pelagic fish (Engraulidae: Clupeidae), with some crustaceans (e.g. Penaeidae: Mysidacea) and cephalopods also consumed. Overall, comparatively few species accounted for most of the prey consumed, indicating that this species is a relatively specialist predator. Teleosts were the most important prey for *C. crysos*. Although, numerically, crustaceans were the most abundant prey group. Other taxa (e.g. molluscs) were of minor importance and may be considered occasional prey. Keenan & Benfield (2003) reported

Table 2. Diet composition of *Caranx crysos* from the Gulf of Gabès (Tunisia) among sex, with the proportion of the diet by frequency of occurrence (%F), number (%N), biomass (%W), IRI and %IRI.

	%F	%N	%W	IRI	%IRI
Sex					
FEMALES					
Teleosts	80.24	37.10	91.26	10298.82	88.44
Crustaceans	18.88	62.61	8.71	1346.45	11.56
Molluscs	0.88	0.29	0.03	0.29	0.002
MALES					
Teleosts	77.48	21.79	89.95	8657.73	81.93
Crustaceans	21.72	78.05	9.85	1908.80	18.06
Molluscs	0.80	0.16	0.20	0.29	0.003

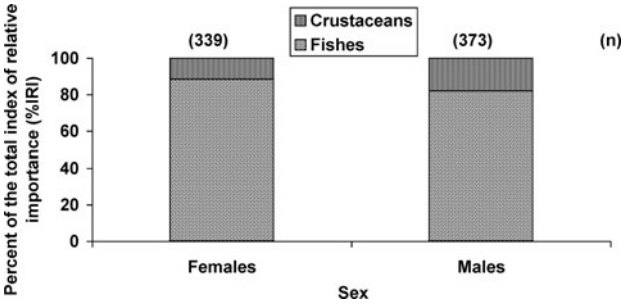

Fig. 3. Diet composition of *Caranx crysos* among sex based on the percentage index of relative importance values of the majors preys groups. n, number of full stomachs analysis in each sex.

that the blue runner *C. crysos*, common around offshore petroleum platforms in the northern Gulf of Mexico, was a zooplanktivorous fish, with larval decapods and stomatopods, hyperiid amphipods, and larval and juvenile fish all common components of its diet. In the West Indies, adult blue runner is considered to be primarily piscivorous (Randall, 1967; Christmas *et al.*, 1974).

Comparable studies about the food habits of other members of the family Carangidae have been carried out in the same region. The results from the present study suggest that the diet of *C. crysos* most closely resembles that of false scad, *Caranx rhonchus* (Sley *et al.*, 2008), with both species feeding primarily on teleosts. However, studies on the diets of horse mackerel, *Trachurus trachurus* from the Tunisian coasts (Fezzani, 2006) and in the central Adriatic Sea (Santic *et al.*, 2004), and pilotfish, *Naucrates ductor* in Sicilian waters indicated that these species fed mainly on zooplanktonic crustaceans, whilst teleosts were of minor importance.

According to the classification of Morato (1998), the most important prey of blue runner in the Gulf of Gabès were anchovy *Engraulis encrasicolus*, which accounted for the greatest proportion of the diet by biomass (%W = 44%), penaeids (*Metapenaeus monoceros* and *Penaeus kerathurus*) and clupeids (*Sardinella aurita* and *Sardina pilchardus*), with mysids (*Leptomysis mediterranea* and *Siriella clausi*) of secondary importance.

Nearly all the fish prey observed were pelagic (*E. encrasicolus*, *S. aurita*, *S. pilchardus* and *Belone belone*). These prey

Table 3. Diet composition of *Caranx crysos* from the Gulf of Gabès (Tunisia) among size-classes, with the proportion of the diet by frequency of occurrence (%F), number (%N), biomass (%W), IRI and % IRI.

	%F	%N	%W	IRI	%IRI
Size					
≤180					
Teleosts	70.67	12.49	78.18	6407.73	67.07
Crustaceans	28.80	87.42	21.80	3145.49	32.93
Molluscs	0.53	0.08	0.02	0.06	0.001
18.1–26					
Teleosts	84.68	58.81	90.74	12664.73	94.79
Crustaceans	13.96	40.55	9.26	695.57	5.21
Molluscs	1.35	0.64	0.07	0.96	0.01
>26					
Teleosts	93.91	96.82	98.23	18317.61	99.86
Crustaceans	5.22	3.18	1.55	24.70	0.13
Molluscs	0.87	0.45	0.22	0.58	0.003

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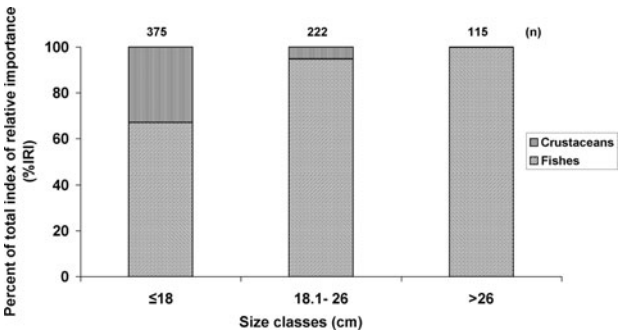

Fig. 4. Diet composition of *Caranx crysos* among size-classes, based in the percentage index of relative importance values of the major preys groups. n, number of full-stomachs analysed in each size.

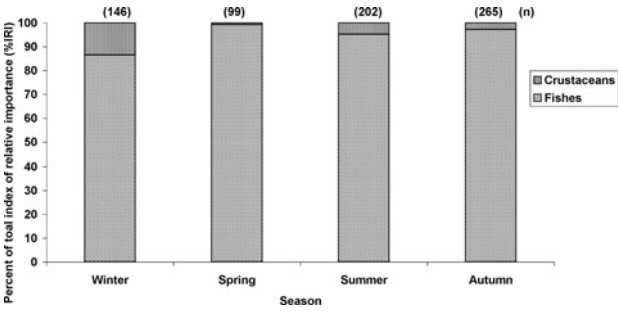

Fig. 5. Diet composition of *Caranx crysos* throughout the year, based in the percentage index of relative importance values of the major preys groups. n, number of full-stomachs analysed in each season.

items, which were only found in the stomachs of fish caught at shallow depths, are common in Tunisian waters (Gaamour, 1999), especially in the Gulf of Gabès. Demersal fish (Gobiidae: Sparidae: Serranidae) were only observed occasionally in the stomachs of blue runner. The present study, as with many others (e.g. McCormick, 1998; Piet, 1998; Jennings *et al.*, 2001; Hanson & Chouinard, 2002; Nakamura *et al.*, 2003) indicates what are important ontogenetic changes in the diet, with the role of fish in the diet increasing with predator size. Stomachs of small-sized fish contained mainly smaller prey than the stomachs of larger-sized fish. The smallest fish ($\leq$18 cm) fed on small crustaceans (mysids and larval fish). As the fish grew (medium size-class; 18.1–26 cm FL, and the large size-class (adults); >26 cm FL), there was an increased preference for fish, mainly *E. encrasicolus* and a declining proportion of crustaceans.

Some data exist on the feeding habits of larval and juvenile blue runner, while accounts of adult feeding habits have been more anecdotal. McKenney *et al.* (1958) and Schekter (1972) stated that blue runner less than 160 mm standard length (SL) were carnivorous planktivores that consumed primarily calanoid and cyclopoid copepods. The size-range of prey in the diets of larger juveniles increased to include zooplankton such as hyperiid amphipods, decapod and stomatopod larvae, and ichthyoplankton (McKenney *et al.*, 1958). Randall (1967) quantified the stomach contents of 17 mature blue runners (190–520 mm FL) from reef habitats in the West Indies; two of these had small silvery fish in their stomachs, while two fish (222 and 250 mm FL) contained 40% planktonic organisms and the remaining contents were fish.

Zooplankton comprised an important part of the diets of mature blue runner in proximity to petroleum platforms in the Gulf of Mexico. Blue runner up to 350 mm FL appeared to consume large numbers (50% by weight) of holoplanktonic and meroplanktonic, mesozooplankton and macrozooplankton. This is contrary to existing literature that characterized mature individuals of this species (>270 mm) as primarily piscivorous (Randall, 1967; Goodwin & Finucane, 1985).

The stomachs of two adult male blue runners (365 and 370 mm SL), collected in Mississippi coastal waters, contained anchovies and two mantis shrimp (*Squilla empusa*) of unstated developmental stage (Christmas *et al.*, 1974).

In our study, the food content of *C. crysos* showed little seasonal variations, as teleosts were the main prey in all seasons, particularly in spring, autumn and summer. Crustaceans constituted a significant part only in winter. Feeding intensity decreased during winter months, as can be deduced from the high number of empty stomachs (>85%). This can be explained either by the unavailability of the prey or by the temperature-dependent physiological process.

The need for larger *C. crysos* to take in enough energy has probably resulted in an increase in their feeding intensities, and this may also explain the decrease in the IV% of larger fish. The spawning season of *C. crysos* has been reported to be from June to August. In the current study, the greater feeding intensity of *C. crysos* coincides with the same time period, which may reflect that the fish require more energy during spawning than in other periods.

Table 4. Diet composition of *Caranx crysos* from the Gulf of Gabès (Tunisia) throughout the year, with the proportion of the diet by frequency of occurrence (%F), number (%N), biomass (%W), IRI and % IRI.

	%F	%N	%W	IRI	%IRI
Season					
SPRING					
Teleosts	90.91	90	97.24	17021.87	99.32
Crustaceans	9.09	10	2.76	116.00	0.68
SUMMER					
Teleosts	87.13	55.61	94.34	13064.90	95.30
Crustaceans	12.87	44.39	5.66	644.22	4.70
AUTUMN					
Teleosts	88.68	64.07	94.51	14062.08	97.24
Crustaceans	9.81	35.21	5.26	397.04	2.75
Molluscs	1.51	0.73	0.23	1.45	0.01
WINTER					
Teleosts	73.97	47.12	90.08	10148.57	86.50
Crustaceans	25.34	52.56	9.90	1583.10	13.49
Molluscs	0.68	0.32	0.02	0.23	0.002

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Correspondence should be addressed to:
A. Sley
Institut National des Sciences et Technologies de la Mer (Centre de Sfax)
BP, 1035, 3018, Sfax, Tunisie
email: sley_aida@yahoo.fr

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